Heart-rate Variability Moderates the Association between Daily Negative Affective Reactivity and Marital Quality: Findings from MIDUS

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ABSTRACT

Multiple recent studies have identified negative affective reactivity as a prospective predictor of physical and mental health outcomes. This study seeks to extend this line of research to relationship outcomes and specifically marital outcomes to see if individual differences in negative affective reactivity can predict these outcomes. Additionally, recent findings have shown links between negative affective reactivity (AR) and high-frequency heart rate variability (HF-HRV), an index of cardiac vagal control. An additional goal was to determine whether HF-HRV moderated the relationship between negative AR and marital quality. We used data from 344 participants who took part in waves II and III of the Midlife in the United States (MIDUS). Respondents completed daily diary measures of stress and affect, a psychophysiological procedure that included HF-HRV measures at rest, and survey scales on marital quality and covariates. We found that negative AR significantly predicted marital risk and marital satisfaction 10 years later and that this relationship was moderated by HF-HRV, which served as a stress buffer.

BIOGRAPHICAL SKETCH

Sam Gardner was born and raised on the Upper West Side of Manhattan. He graduated from the College of William and Mary in 2015 with a Bachelor of Science degree in Psychology. He subsequently lived for two years in Houston, Texas working in psychiatry research and education before attending Cornell University to complete his M.A. in Human Development in 2018. He is grateful for this opportunity and looking forward to pursuing new intellectually challenging and socially engaging horizons.

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CHAPTER 1

Introduction

Daily diary measures (also referred to as ambulatory assessments or experience sampling measures) offer a variety of systematic ways to examine links between stress and health outcomes (Eckenrode & Bolger, 1995). Daily measures of stress include a number of factors involved in the stress process such as exposure, stressor type, stressor severity, and affective reactivity (Almeida, Wethington, & Kessler, 2002). Studies of how these stress processes are involved in individual differences concerning mood and health outcomes is a line of research that has contributed to and can further inform understandings of well-being and disease risk. In their book chapter on personality and stress, Williams, Smith, Gunn, and Uchino (2011, Figure 1) promote a model in which individual differences in stress processes are dynamically and reciprocally associated with physical and mental health outcomes. The authors discuss how individual differences in stress processes are dynamically and reciprocally associated with personality and in total, the model offers ways of understanding how individuals develop and adapt stress responses that are both influenced by and predictive of differences in health.

The stress factor focused upon in this paper is negative affective reactivity (AR) to stress. The daily approach to AR as utilized in stress-health studies functions as a mixed-methods approach that includes both within-persons and between-persons operations (Mroczek, Spiro, & Almeida, 2003; Ong & Ram 2017). This mixed-methods approach yields a trait-like indicator of psychological vulnerability to stressors that can indicate potential negative health outcomes (Sin, Graham-England, Ong, & Almeida, 2015). AR research has built evidence that while the number and severity of stressors have implications for individual future health, the response to stress and the fluctuation in mood resulting from a stressor may be more consequential.

A number of studies have analyzed negative AR as a predictor of physical and mental health outcomes. Outcomes have included depressive symptoms (Booij, Snippe, Jeronimus, Wichers, & Wigman, 2018; Parrish, Cohen, & Laurenceau, 2011), self-reported affective disorder (Charles, Piazza, Mogle, Sliwinski, & Almeida, 2013), self-reported chronic illness

(Piazza, Charles, Sliwinski, Mogle, & Almeida, 2013), and mortality risk (Chiang, Toriano, Mroczek, & Miller, 2018). In these studies, affective reactivity has been characterized as: a marker of vulnerability for depression (Booij et al., 2018), an indicator of increased emotional sensitivity (Parrish et al. 2011), a correlate of neuroticism (Charles et al., 2013), a precipitator of wear-and-tear physiological processes (Piazza et al., 2013), and a sign of dysregulated health-restoring processes (Chiang et al., 2018). While these studies found negative AR to be a significant predictor of future health outcomes, Mroczek and colleagues (2013) found that positive AR but not negative AR was a significant predictor of mortality risk among middle-aged and older veterans 10 years later. With such varied understandings of daily negative AR, there is a need to ground the theoretical underpinnings of daily affective reactivity within the broader theoretical framework of stress-health prospective research for this study.

In this study, we use marital satisfaction and marital risk as the health outcome variable. Williams et al.'s (2011) model of personality and stress regulation does not include relationship factors howeverit is not a stretch to add relationship health to the physical and mental health outcomes section. While relationship quality may seem to be out of place as the dependent variable in a stress-health model, both theoretical and empirical research have shown that relationship health is a key aspect of overall health and related to more traditional health aspects (Selcuk & Ong, 2013; Zlotnick, Kohn, Keitner, & Della Grotta, 2000). Slatcher and Selcuk's (2017, figure 2) strength and strain model of marriage and health demonstrates ways in which relationship stressors, relationship strengths, and outside stressors can interact to produce stress-intensifying or stress-buffering effects that contribute to physical health outcomes. This model includes positive and negative affect as psychological mechanisms howeveraffective reactivity best fits in the individual differences section of the model. This allows for direct effects of negative AR on marital strength and marital strain. For the purposes of this study, a simplified model is shown in Figure 3 to demonstrate the main daily stress-health effect in the marital context.

Randall & Bodenmann (2009 & 2017) have written two review papers on the association between stress and close relationship satisfaction and found a persistent negative association (r = -.3 to -.5 as cited in Bodenmann & Cina, 2006). In light of the evidence, the reviews proposed that external, chronic, minor stressors (a stressor-type often captured in diary AR measurements) are most closely associated with low relationship satisfaction. In addition to stressor type, stress physiology as indicated by diurnal cortisol levels has also been shown to be associated with higher morning peaks and steeper declines during the day found for those with higher marital satisfaction (Saxbe, Repetti, & Nishina, 2008).While most stress-close relationship studies have employed a cross-sectional approach, Bodenmann & Cina (2006) used a longitudinal prospective design with 62 couples from a Swiss community sample and found that a combined factor that included stress, individual coping, and dyadic coping at T1 predicted whether a couple was stable-satisfied, stable-unsatisfied, or separated/divorced five years later in 62.1% of cases. Another longitudinal study with 169 newlywed couples from Florida found mixed results in the covarying relationship between workload and marital satisfaction with moderators of gender, parental status, and workload satisfaction all playing a role in the marital satisfaction outcome over four years (van Steenberger, Kluwen, & Karney, 2011).

In addition to the broader relationship between stress and marital satisfaction, a number of studies have included measures of affective reactivity in investigations of close relationship quality. Auger, Menzes-Toman, & Lydon (2017) sampled university student couples with a 2-week diary method to examine several possible links between relationship identification level, daily negative affective reactivity to partner transgressions, and global relationship satisfaction. As part of an exploratory analysis they found that daily negative AR to partner transgressions did not have a direct effect on relationship satisfaction however they did find a significant interaction effect of daily negative AR and relationship identification on global relationship satisfaction. They suggested that high relationship identification may serve as a buffer against the lingering effects of recent negative relationship experiences. Tolpin and colleagues looked at relationship satisfaction as a predictor of the number of daily positive and negative romantic relationship

(RR) events, daily AR to RR stressors, and the moderating role of depressive symptoms (Tolpin, Cohen, Gunthert, & Farrehi, 2006).They found that high initial relationship satisfaction actually predicted higher PA reactivity to RR stressors and suggest that this might be the product of a tolerance adaptation by those who experience lots of relationship stressors. While these studies used diary methods, the outcome variables were measured within weeks or months of the diary study. No studies have looked at the long-term prospective relationship between AR and close relationship outcomes.

More research is needed to clarify the direct link between AR and marital quality and the possible influential mechanisms and factors. One mechanism that likely plays a key role in this process is emotion regulation. Pietromonaco, Barrett, & Powers (2006) suggest that the two affective-based processes underlying adult attachment are AR and affect regulation. As an extension of Bowlby's work on attachment in the infant-caregiver relationship, Hazan and Shaver (1987) posited that adult romantic relationships operate according to similar processes. Partners seek each other out as a means of dealing with a threat, and a key aspect of romantic relationships is the ability of partners to aid in and receive the benefits of regulating distress. In a 14-day daily diary study of newly married couples, Buck and Neff (2012) found that the main effect of partners' daily stressors on both negative marital behaviors and daily marital appraisals was significant. These findings are interpreted as support for a stress spillover understanding of stress and relationships such that external stressors spill over into the relationship. Additionally, Buck and Neff found that self-regulatory depletion played a significant mediating role in the relationship between partners' daily stress and daily marital appraisals such that poor relationship functioning on high stress days was accounted for by the inability to inhibit negative thoughts and behaviors. This evidence suggests that affective regulation on both the individual and dyadic level may play an important role in the link between affective reactivity and marital satisfaction.

The models proposed by Williams and colleagues (2011, Figure 1) and Slatcher and Selcuk (2017, Figure 2) both include cognitive, biological, and environmental factors that could play a role in the direct effects of AR on marital quality. The influence of personality on an

individual's stress profile (Williams et al., 2011) or the feedback of physical health into stress experiences (Slatcher & Selcuk, 2017) are both useful and important considerations in understanding how we may best model the influence of AR on marital quality. In order to simplify the causal model and clarify the focus, Figure 3 shows the direct effect of negative AR on marital quality as well as a moderating effect of heart rate variability. While this causal relationship can be inferred with some more maneuvering in Figures 1 and 2, Figure 3 omits many factors that may be involved in the negative AR-marital quality relationship and focuses on the potential moderating role of heart rate variability.

Heart rate variability is a psychophysiological marker of affect regulation that has been theorized and tested. Within the autonomic nervous system (ANS), the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) function antagonistically with SNS activation increasing heart rate and PNS decreasing (Appelhans & Luecken, 2006). Heart rate variability (HRV) can be measured in multiple ways and generally refers to the variability in interbeat R-R intervals on an ECG. HRV is understood to partially be a product of respiratory sinus arrhythmia (RSA) – the rhythmic oscillation in heart rate produced by respiration. During inspiration, the interbeat R-R interval is shortened while during expiration, the R-R interval is prolonged. Researchers have often interpreted RSA to be an index of cardiac vagal tone or control of heart rate however Pyetan, Toledo, Zoran, and Axelrod (2003) have contested the widely held notion that vagal tone is linearly related to RSA. Instead, Pyetan and colleagues' (2003) experimental model suggests that RSA measures of HRV reflect modulation of cardiac vagal outflow from the brain to the heart (for more on RSA, see Bernardi, Porta, Gabutti, Spicuzza, & Sleight, 2001 and Yasuma & Hayano, 2004).

Two key theories have posited heart rate variability as a biomarker of emotion regulation: polyvagal theory (Porges, 1995 & 2007) and the neurovisceral integration model (Thayer & Lane, 2000; Thayer, Hansen, Saus-Rose, & Johnson, 2009). Polyvagal theory theorizes that heart rate variability is a signature of the parasympathetic vagal system's ability to regulate cardiac activity and concomitant socio-behavioral functions (Porges, 2007, figure 1). The central concept

within polyvagal theory is the "vagal brake," phylogenetically distinct to mammals and consisting of myelinated pathways between the brain's nucleus ambiguus and the heart's sinoatrial nerve. These pathways facilitate modulation of visceral states (sympathetic nervous functions and HPA-axis activity) that enable rapid engagement or disengagement from environmental stimuli (Porges, 2007). Porges extended his theory to mammalian love and implicated the vagal complex in mate selection, courtship, and sexual behavior (Porges, 1998). The overall implication of the polyvagal theory is that heart rate variability is modulated by a complex system that has evolved significantly over time in order to produce efficient neuronal responses to varied social situations that allow people to adapt to contexts and self-regulate based on the demands of the situation.

The neurovisceral integration model focuses on how functional brain networks such as the central autonomic network facilitate coordinated cardiac, affective, attentional and behavioral responses in goal-directed behavior and adaptability (Thayer & Lane, 2000). Similar to polyvagal theory, neurovisceral integration also focuses on HRV as a measure of one's ability to self-regulate with respect to changes in the internal and external environment. HRV is an index through which researchers can identify structural links between psychological and physiological processes related to vagal regulation of heart rate, and Thayer and his colleagues have extended this work to numerous domains such as cardiovascular disease, allostatic systems, and executive functioning (Thayer, 2009). Thayer et al. (2012) in a meta-analysis of studies that measured HRV and collected neuroimaging claim that the data show support for HRV as a marker of individual ability to appraise and respond to stress and potential cognitive and physical health problems associated with low HRV. According to the model, low HRV results from disrupted inhibitory neural networks that are central to the parasympathetic vagal function of regulating heart rate.

Numerous studies have investigated HRV as a factor in biopsychosocial contexts of health and relationship variables (for reviews, see Appelhans & Luecken, 2006; Balzarotti, Biassoni, Colombo, & Ciceri, 2017). Diamond and Hicks (2005) studied resting RSA as a

mediator in the relationship between reactivity to anger-inducing stimuli and global attachment styles in a sample of university-aged men. They found that high resting-RSA was positively associated with perceptions of security in current attachment relationships, negatively associated with overall attachment anxiety, and mediated the relationship between anger reactivity (but not distress reactivity) and perceived relationship security with faster recovery times. In a dyadic study of romantic couples' coregulation of HRV during interactions, couples with greater HRV dependence showed greater marital satisfaction (Helm, Sbarra, & Ferrer, 2014). Kok & Fredrickson (2010) found that resting RSA levels at the beginning of a nine-week daily diary study positively predicted increases in social connectedness and positive affect and increases in social connectedness and positive affect over the course of the study positively predicted vagal tone at the end of the study. They propose that these findings demonstrate a cyclical pattern in which HRV, social connectedness, and positive affect spiral upwards over time in a continuously reinforcing cycle. This model highlights the dynamic interconnectedness between physiological, affective, and relationship variables in the context of HRV.

How HRV fits in a broader stress-health model linking affective reactivity and marital outcomes is not clear. One possibility is that resting HRV moderates the association between RSA and affective reactivity. Diamond, Hicks, and Otter-Henderson (2011) took this approach with HRV in a relationship study and found that for men, daily negative affect was more strongly associated with daily negative partner interactions for those with low vagal tone while for women, daily positive affect was more strongly associated with daily positive partner interactions for those with high vagal tone. While these findings suggest that both high HRV and low HRV accentuate the positive linear associations between positive affect and positive relationship outcomes and negative affect and negative relationship outcomes respectively, there is evidence that higher resting RSA may actually be a marker of greater negative emotional reactivity (Butler, Wilhelm, & Gross, 2006). Another study using a moderating model demonstrated that HRV may serve as a stress-buffering factor against hostile behaviors in conflict with their partners among highly rejection-sensitive people (Gyurak & Ayduk, 2008).

Lischke et al.'s (2018) work demonstrating links between individual differences in HRV and individual differences in empathy and alexithymia provide additional evidence in favor of a possible moderating model.

In addition to a moderating model, it is important to consider other possible relationships between HRV in the affective reactivity – marital quality link. Gyurak & Ayduk's (2008) study might be interpreted as evidence that HRV has independent links with both affective measures and interpersonal measures. Multiple studies have independently linked HRV with measures related to affective reactivity such as affective states (Duarte & Pinto-Guveia, 2017), daily worry (Brosschot, van Dijk, & Thayer, 2007), and startle reactivity (Panayiotou & Constntinou, 2017; Yang & Friedman, 2007). Because these three aspects of biopsychosocial health have been closely interlinked in a variety of ways, it may be that a cyclical model as proposed by Kok et al. (2010) is more fitting. One study demonstrating a link between negative AR and HRV has suggested that the influence of the two variables on one another may be bidirectional (Sin, Sloan, McKinley, & Almeida, 2016).

The goal of this study is to answer two main questions. The first question is whether negative AR predicts marital quality outcomes 10 years later. Based on the evidence linking negative AR to prospective health outcomes, research on AR and close relationship factors, and more general stress-close relationship research, I predict that negative AR will be a significant predictor for marital quality outcomes. The second question is whether HRV plays a moderating role in the relationship between negative AR and marital quality. Prior research has demonstrated that HRV is linked to affect, stress, and relationship outcomes and may play a moderating role in stress-health relationships. Conceptualizing HRV as a marker of emotion regulation suggests a mechanism for understanding how people with higher negative affective reactivity to stress may be protected in their long-term marriage quality by the ability to better regulate their emotions despite their high negative affect. This understanding of HRV implicates HRV as a stress buffer against the negative effects of negative AR on marital quality. I predict that HRV is a significant moderator of the negative AR-marital quality relationship and may play a stress buffering role.

CHAPTER 2

Methods

Sample

The national survey of Midlife Development in the U.S. (MIDUS) is a multi-project and multi-method longitudinal study of the behavioral, psychological, and social factors involved in health and well-being. 3,294 participants completed the MIDUS general survey at waves 2 and 3, the two waves of interest in this study. We limited the sample to participants consistently married over the course of MIDUS II and III (n = 2047) and will examine participants who also took part in multiple representative subprojects at MIDUS II: the national survey of daily experiences (NSDE) (n = 2022) and the biomarker project (n = 1255). When all these criteria are met, the study sample comes to 413 participants. Of these 413 participants, 69 were missing data on at least one outcome variable or covariate leading to a final sample of 344.

Of the 69 participants excluded from the study because of missing data, 40 participants out of the sample of 413 (9.7%) did not have complete data for marital risk outcome. Most of these excluded participants did not complete the SAQ data at MIDUS III (37/40). Like MIDUS III marital risk, 40 of the 413 participants were missing marital satisfaction data and excluded from the study however only two additional people were excluded from the sample when accounting for missing marital risk data. 27 participants were excluded from the analysis because of missing data on at least one covariate. 11 participants were excluded because of missing BMI, 9 participants were excluded because of missing household income data, 4 participants were excluded because of missing trait NA scores, 2 participants were excluded because of missing scores for MIDUS 2 marital risk, and 1 participant was excluded for missing a MIDUS 2 marital satisfaction score.

Projects and Procedures

MIDUS II and III. The MIDUS III general survey contained a self-administered questionnaire (SAQ) with multiple self-report scales and a telephone interview. Within the SAQ, both marital satisfaction and marital risk were assessed in different scales.

NSDE II. The NSDE II consisted of telephone interviews on 8 consecutive evenings and included the Daily Inventory of Stressful Events (DISE; Almeida et al., 2002), an instrument assessing various types of stressors and reactions to stressors experienced in the last 24 hours. Categories of stressors included argument, avoided argument, stressful work/school event, stressful home event, discrimination, network stressor (event happened to a close friend or relative), and other. Days on which at least one stressor was reported were coded as "stressor days" (74% of stressor days had only one stressor). "Stressor frequency" referred to the percentage of days for which a stressor occurred.

Biomarker II – Psychophysiology Procedure. The Biomarker II consisted of a two day visit including an overnight stay at one of three clinical research centers (UCLA, Georgetown University, and University of Wisconsin-Madison). The protocol for each participant included a physical health exam, blood and urine samples, and a psychophysiological experiment. Included in the psychophysiological experiment was an ECG exam that allowed for calculations of HRV.

Additionally, participants were asked to complete several self-report measures during the biomarker project including the Perceived Stress Scale, which included six items about stressors in the last month.

Measures

Primary Predictors and Outcomes.

Negative Affective Reactivity. Negative affect with respect to stressors was measured each day in the DISE portion of the NSDE. Participants were asked four questions concerning how angry, nervous or anxious, sad, and shameful they felt in response to the stressor. Researchers are able to calculate negative AR scores for each participant using a two-level approach from the data. The purpose of AR scores is to calculate the difference in affect between days when individuals do not experience a stressor and days when they do. The written equation for this model is written as such (Sin et al., 2015):

Level 1 (day-level):

$$Affect_{di} = a_{0i} + a_{1i} + \mathbf{e_{di}}$$ (difference in negative affect between non-stress and stress days)

Level 2 (person-level):

$$\mathbf{a_{0i}} = \beta_{00} + u_{0i}$$ (average negative affect on non-stressor days for sample)

$$a_{1i} = \beta 10 + u_{1i}$$ (average affect on stressor days for sample)

The first level shows within-persons differences in affect between days (*d*) when participant *i* reported experiencing no stressors (a_0) and the slope increase in negative affect on days when participants reported experiencing at least one stressor (a_1) and accounts for the residual day-to-day variability for person *I* (e_{di}). The second level shows between-persons differences in level 1 scores. The target score included in the analysis for each individual is a_{1i}.

Heart-rate variability. As part of the Biomarker psychophysiological experiment, participants underwent 11 minute resting baseline ECGs to detect R-waves and reveal RR interval series. High frequency HRV (HF-HRV -- 0.15-0.40 Hz) was calculated based on 300-s

epochs and the mean value HF-HRV was calculated from two epochs while the last 60 seconds were excluded (Sloan et al., 2017).

Marital Risk. The marital risk scale in the SAQ of MIDUS III contained two questions -- one question about perceived relationship risk in the past year and one question about perceived risk in the future ($\alpha = .66$).

Marital Satisfaction. The life satisfaction (domain specific) scale in the SAQ of MIDUS III included a single item asking participants to rate their relationship with their partner on a scale from 0 to 10.

Covariates.

Stress Frequency and Demographics. From the NSDE data, stressor frequency is calculated as the percentage of days that a participant experienced a stressor. This is relevant as a covariate because the frequency with which a participant experiences stress likely affects baseline negative affect, which could be consequential in calculations of negative AR. We also controlled for age, gender, race (white vs. nonwhite similar to other MIDUS studies), and household income. Studies have shown that age differences play a role in daily affect and emotional experience (Charles, Mogle, Leger, & Almeida, 2017). Diamond et al. (2011) demonstrated gender differences in daily affect and HRV. Differences in reactivity to stress according to race have been demonstrated (Birditt, Cichy, & Almeida, 2011). Additionally, income and SES have been associated with number of stressors and modulation of the stress response (Steptoe & Feldman, 2001; Gryzwacz & Almeida, 2008). The two outcome variables -- marital risk and marital satisfaction – were controlled for at MIDUS II (baseline for this study).

Physical Health and Health Behaviors. BMI, number of chronic health conditions, regular exercise, and sleep quality were all included in the model controlling for physical health.

BMI has been shown to be associated with differing levels of PA and NA and ability to manage stress (Carr, Friedman, & Jaffe, 2007; Roberts et al.). Multiple studies have linked affective reactivity to chronic health conditions (Piazza et al., 2013; Chiang et al., 2018). No studies have directly linked AR and regular exercise, however studies have shown that regular exercise has strong associations with resting HRV (Levy et al., 1998). Sleep quality was calculated from a single item in the Pittsburgh Sleep Quality inventory during the biomarker study. Lab experiments have demonstrated a significant relationship between PA reactivity and sleep quality (Ong, Exner-Cortens, Riffin, Steptoe, Zautra, & Almeida, 2013) and found sleep to be a buffer of reactivity to stress and pain (Hamilton, Catley, & Karlson, 2007).

***Personal Characteristics*.** Neuroticism was measured with a four item scale for which participants rated on a scale of 1-4 how well the words moody, worrying, calm, and nervous described them. It has been theorized as a correlate of affective reactivity, and an empirical study has shown relationships between negative affect instability and neuroticism (Charles et al, 2013; Miller, Vachon, & Lynam, 2009). Perceived stress was measured during the biomarker study with a ten item scale with items asking participants about different aspects of stress in the past month ($\alpha = .86$). Trait negative affect scores were calculated from a scale in the MIDUS II survey which asked participants to self-report on five negative adjectives from the Positive and Negative Affect Schedule: afraid, jittery, irritable, ashamed, upset. These scales were included as controls for negative AR as the tendency to perceive and self-report high amounts of stress and negative affect may be associated with higher negative AR scores.

Data Analysis

Five different models were chosen to analyze the ability of negative AR and HRV to predict marital quality outcomes. Marital risk and marital satisfaction at MIDUS III were the two

outcome variables, and the five models were applied to each outcome separately to create a total of ten models (models 1a-5a: marital risk; models 1b-5b: marital satisfaciion). Model 1 was unadjusted and only included negative AR and HRV as independent predictors of marital risk 10 years later. Models 2-4 included classes of covariates that have been shown to be associated with negative AR and HRV. Each subsequent model for models 1a-a5 included the covariates from the previous model and model 5 included all covariates and the interaction term of interest. Models 1b-5b were identical to 1a-5a except that the outcome variable was changed to marital satisfaction and MIDUS II marital satisfaction is included as a covariate at model 2b instead of MIDUS II marital risk.

Models 1-5:

Model 1 (unadjusted): Negative AR and HRV as independent predictors of marital risk/marital satisfaction.

Model 2 (Demographics + stressor frequency and MIDUS II Marital Risk): Model 1 + covariates: age, sex, race (white vs. non-white), stressor frequency (% of days with one stressor, household income, and marital risk at MIDUS II

Model 3 (physical health + health behaviors): Adjusts for BMI, number of chronic health conditions, regular exercise, and sleep quality as well as model 2 covariates.

Model 4 (personal characteristics): Adjusts for neuroticism, perceived stress, and trait anxiety as well as all covariates in model 3

Model 5 (full): Interaction between negative AR and HRV as a predictor of marital risk and adjusting for main effects and all covariates in models 2-4.

Analyses for all multiple linear regression models were performed in SPSS and the interaction models were calculated using the PROCESS macro. The same analyses were performed in R using the lm method and the jtools package to obtain test statistics and create figures. Pearson's *r* correlations were obtained from the Hmisc package in R. In order to test whether the exclusion of participants missing data on covariates (69/413, 16.7 %) contributed to effects in the analysis, multiple imputations were performed to fill in missing values and test the full models for both marital risk and marital satisfaction. Five imputations were completed for each model using the mice package in R with the predictive mean matching method.

CHAPTER 3

Results

Descriptive statistics and Pearson r correlations for all variables are reported in Table 1. The average age of the sample was 54.6 years old, 51.6 % of participants were female, and 95.1 % of the sample was white, and the median household income was $76,000. Among the correlations between the central parameters and covariates, both MIDUS 2 marital risk and marital satisfaction were strongly correlated with the respective scores at MIDUS 3. Stressor frequency showed a significant positive correlation with negative AR (r = .239, $p < .001$). Notably, none of BMI, number of chronic health conditions, or regular exercise had any significant correlations with either of the main predictors or outcomes. Sleep quality was significantly correlated with marital risk at MIDUS 3 (r = .127, p < .05) however it was not correlated with marital satisfaction. Neuroticism, perceived stress, and trait NA were all significantly correlated with marital risk and negative AR suggesting that these variables could play a role in marital risk models.

Predicting Marital Risk 10 years later

Across the five different models predicting marital risk at MIDUS III, main effects of negative AR and HRV were significant at the p < 0.05 in all models level except for negative AR in the full interaction model (p = 0.13). The full interaction model (model 5a) accounted for 27.7% of the variance in marital risk 10 years later and showed significant predictive ability, (R^2 = 0.28, $F(16, 327) = 7.83$, $p < .001$,). The interaction effect of negative affective reactivity and HF-HRV on marital risk with all continuous covariates mean-centered was significant (β = -1.73, $SE = 0.60$, $p < .01$, 95% CI [-2.91, -0.54]). Covariates that showed significant predictive ability at p < .05 were marital risk at MIDUS II, age, and perceived stress. The model was retested with

participants excluded due to missing data using multiple imputations data and the interaction effect remained significant across all five imputations ($p < .05$).

The conditional effects of the interaction are shown in Figure 4. Analysis followed Preacher, Curran, and Bauer's (2006) approach to simple slopes for multiple linear regressions. The simple slope was 3.17 ($p < .01$) for low HF-HRV participants at 1 *SD* below the mean, 1.15 ($p = 0.19$) for average HF-HRV at the mean; and -.087 ($p = 0.47$) for high HF-HRV participants at 1 *SD* above the mean. The simple slope results show that low HF-HRV participants drove the moderating effect of HRV on the negative AR-marital risk relationship such that low HRV participants were more likely to report increased marital risk when they had high negative AR scores compared to the likelihood that high HRV participants would report reduced marital risk when they had low negative AR.

Predicting Marital Satisfaction 10 years later

Across the five different models predicting marital satisfaction at MIDUS III, main effects of negative AR were significant at the $p < 0.05$ level except for the full interaction model ($p = 0.13$). The main effect of HF-HRV was significant in the unadjusted (model 1b) at the $p < 0.05$ level but was not significant in adjusted models 7-9. The full interaction model accounted for 38.7% of the variance in marital satisfaction 10 years later and showed significant predictive ability ($R^2 = 0.39$, $F(16, 327) = 13.77$, $p < .001$,). The moderating effect of HRV on the relationship between negative AR and marital satisfaction with all continuous covariates mean-centered was significant ($\beta = 2.87$, $SE = 0.68$, $p < .001$, 95% CI [1.55, 4.19]. The covariates that showed significant predictive ability at $p < .05$ in this model were marital satisfaction at MIDUS II, age, and perceived stress. The model was retested with participants excluded due to missing data using multiple imputations data and the interaction effect remained significant across all five imputations ($p < .01$).

The conditional effects of the interaction are shown in Figure 5. The simple slope was 4.64 ($p < .001$) for low HF-HRV participants (-1 *SD* below the mean), -1.15 ($p = 0.14$) for average HF-HRV participants, 2.07 ($p = 0.13$) for high HF-HRV participants (+1 *SD* above the

mean). Similar to the simple slope results for the marital risk interaction model, these results show that low HF-HRV participants drove the moderating effect of HRV on the negative AR-marital satisfaction relationship such that low HRV participants were more likely to report lower marital satisfaction when they had high negative AR scores compared to high HRV participants proclivity to report high marital satisfaction when they had low AR scores.

Chapter 4

Discussion

Negative AR as a Prospective Predictor of Marital Quality

The first main question of this study was whether negative AR predicted marital quality outcomes ten years later. Results from models 1-4 for marital risk and marital satisfaction showed that negative AR was a significant predictor of both outcomes in unadjusted and adjusted models. This finding is consistent with the hypothesis and prior research showing that negative AR is a prospective predictor of health outcomes (Charles et al., 2013; Chiang et al., 2018; Piazza et al., 2013). Additionally, this finding is consistent with Slatcher and Selcuk's (2017) strength and strain model as individual differences in affect reactivity are significant predictors of global marital risk and marital satisfaction measures. This finding also suggests an extension of Williams and colleagues (2011) model of personality and stress to relationship outcomes.

These results have implications for how to approach research on marriage and close relationships. Studies have identified and employed affective reactivity as a measure in relationship research and found that it is associated with relationship outcomes (Auger et al., 2017; Tolpin et al., 2006). However, these studies have not taken a long-term prospective approach to understanding the ways in which affective reactivity to stress can predict relationship outcomes. Further research might illuminate ways in which daily stress processes can influence relational health and potential mechanisms for mitigating the expected negative outcomes. This research also can inform how clinicians approach their work with patients as understanding a patient's stress profile may be an important criteria for maximizing the effectiveness of clinical work.

HRV as a Moderator of Negative AR-Marital Quality Relationship

The second main question of this study was whether HRV as indicated by HF-HRV moderated the relationship between negative AR and marital quality. Results from both model 5 interactions showed that HRV did moderate this relationship significantly for both marital risk and marital satisfaction. This finding is consistent with the hypothesis and evidence showing HRV as an emotion regulation indicator with links to both stress and health (Appelhans & Luecken 2006; Thayer et al, 2012). Probing the interactions with simple slopes analysis revealed that the slopes were only significant for low-HRV participants who showed greater marital risk at high negative AR as compared to low negative AR and reduced marital satisfaction at high negative AR. The mitigation of the association at average and high HRV levels suggest a stress buffering effect for those without low HRV whereby having average or higher HRV protects against the negative effects of high negative AR.

Understanding HRV as a stress buffer is an important finding as it means that finding ways to improve HRV to average levels could be important in terms of relational health. Although regular exercise itself was not a significant predictor of marital quality, it could be that exercise programs geared towards improving HRV could have significant benefits for marital outcomes over the long run. Moreover, determining the underlying etiological development of stress processes within the low-HRV sample would be useful in determining more specifically what it is about low-HRV people that make them more vulnerable to the ill-effects of high negative AR. This could have ramifications for behavioral therapy and couples counselling and could spur no methods for treating people who have negative AR and appear to be at high risk.

Limitations and Future Directions

While the MIDUS dataset offers large and nationally representative samples across a variety of measures, there are shortcomings that should be considered. The sample in the current

study was overwhelmingly white, which is a shortcoming of a number of MIDUS subsamples. Additionally, the mean of negative AR when participants missing data on covariates were included (N = 413) was significantly greater than the mean when those participants were not included (N = 344, 9.6 % greater mean). This suggests that participants with missing data may have had different stress profiles than those who did not. However, multiple imputation tests revealed that the interaction effect remained significant for predicting marital risk and marital quality.

One challenge of the NSDE's methodology of determining daily stress and affect is that the end-of-day phone assessment, while an improvement over checklist methods, is still susceptible to recall biases. Those reporting increased stress and greater negative affect may be doing so because of slower emotional recovery from the stressor compared to another participant who had a similar AR stress experience but recovered from it more quickly (Sin et al., 2016). Ecological momentary assessments of affect and stress would be optimal in studying individual differences affective reactivity to stress.

Additionally, HF-HRV was measured at rest in this study. While this is useful in understanding baseline levels, it may be that HRV changes during a stressful situation are also integral in terms of responding to stress, especially with regard to relationship outcomes. Looking into resting HRV and changes in HRV over time and in response to stressors would go further in explaining the complexities of individual differences in stress responses and the potential to predict relationship health.

Even with these limitations, this study can be extended in multiple directions for the future. Having established that negative AR is a prospective predictor of marital quality 10 years later, it would be worthwhile to also investigate whether the same holds true for positive AR.

Additionally, dyadic studies investigating whether being married to a partner who has negative AR and low-HRV has inter-individual effects within the relationship could explain processes that increase the likelihood of separation or how partners can mitigate the ill-effects of negative AR and low-HRV. Future studies have a basis from which to further probe the prospective relationship between AR and marital quality and the underlying processes by which stress buffering effects may take hold and the conditions under which buffering is most likely. Moreover, reciprocal effects whereby marital quality may also predict affective reactivity could be a fruitful line of research. While trying to focus on stress processes as a means to ensure better long-term relationship health may be one solution, another may be focusing on the relationship itself and maximizing its quality, which may have beneficial effects on stress long-term.

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Tables

Table 1. Descriptive Statistics and Pearson's r correlations among all variables included in analyses (N = 344)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. M3 Marital Risk	____																	
2. M3 Marital Sat	-.728***	____																
3. Negative AR	.190***	-.189***	____															
4. HF-HRV	-.147**	.125*	-.091	____														
5. M2 Marital Risk	.408***	-.361***	.092	-.098	____													
6. M2 Marital Sat	-.336***	.540***	-.090	.126*	-.465***	____												
7. % of days w/ stressor	.101	-.171**	.239***	.024	.162**	-.168**	.-----											
8. Age (Years)	-.197***	.219***	-.093	-.286***	-.172**	-.227**	-.156***	____										
9. Sex[a]	.003	-.065***	-.043	.125*	.010	.034	-.045	-.158**	____									
10. White/non-white[b]	.029	-.063	-.018	-.084	-.017	-.021	-.033	.056	-.058	____	.							
11. HH Total Income	-.080	0	-.030	-.071	-.009	-.056	.040	-.177**	.012	.011	____							
12. BMI	.086	-.054	.078	-.090	.050	-.080	.032	.017	-.055	-.144**	-.054	____						
13. # of Chronic Conditions	.072	-.056	.053	-.094	.060	-.052	.093	.105	.106	.010	-.056	.278***	____					
14. Regular Exercise[c]	-.051	.065	0	-.045	-.060	.099	-.007	.088	-.064	-.029	-.001	.075	-.021	____				
15. Sleep Quality	.127*	-.064	.093	.013	.110*	-.065	.138*	-.034	.082	-.013	-.048	.098	.222***	.060	____			
16. Neuroticism	.114*	.112*	.315***	-.015	.168**	-.120	.163**	-.217***	.098	-.028	.053	-.026	.242***	-.099	.218***	____		

17. Perceived Stress	.232***	-.208***	.340***	-.018	.194***	-.139	.278***	-.134*	.031	.005	-.099	.073	.190***	.013	.262***	.499***	____	
18. Trait Negative Affect	.135*	-.095	.292***	.004	.192***	-.174	.188***	-.205***	-.044	-.052	-.002	.085	.293***	-.086	.232***	.581***	.463***	____
M (or *N*)	2.88	8.47	0.16	4.77	2.80	8.46	0.41	54.64	179 fem	327 W	918 71.76 641	27.59	2.02	280 yes	1.91	1.95	21.07	1.47
SD	1.39	1.69	0.10	1.17	1.15	1.42	0.22	10.24	0.50	0.22	56.24	5.39	1.92	0.39	0.61	0.61	5.78	0.41
Cronbach's α	..66	.	.	.	.	.59	.		.	.	-						.86	

Note. Age is age at MIDUS 2.

[a] 1 = Male, 2 = Female

[b] 1 = White, 2 = Non-white

[c] 1 = Yes, 2 = No

* p < 0.05. ** p < .01. *** p < .001

Table 2. Multiple linear regression statistics for models predicting marital risk

	Model 1a (Unadjusted)		Model 2a (Stressor Frequency and Demographics)		Model 3a (Physical Health and Health Behaviors)		Model 4a (Personal Characteristics)		Model 5a (Interaction)	
Parameter	*β* (*SE*)	*p*	*β* (*SE*)	*p*	*β* (*SE*)	*p*	*β* (*SE*)	*p*	*β* (*SE*)	*p*
Intercept	**2.88 (0.07)**	**<.001**	**2.67 (0.31)**	**<.001**	**2.67 (0.32)**	**<.001**	**2.73 (0.32)**	**<.001**	**2.69 (0.32)**	**<.001**
Predictor and moderator										
Negative Affect Reactivity	**2.53 (0.76)**	**<.001**	**1.78 (0.71)**	**.002**	**1.68 (0.71)**	**0 .02**	**1.62 (0.75)**	**0.03**	1.15 (0.76)	0.13
HF-HRV (0.15-0.5 Hz)	**--0.15 (0.06)**	**.014**	**-0.20 (0.06)**	**0 .01**	**-0.19 (0.06)**	**.002**	**-0.19 (0.06)**	**0.002**	**-0.20 (0.06)**	**0.001**
Stressor Frequency and Demographics										
Marital Risk (MIDUS 2)			**0.42 (0.06)**	**<.001**	**0.41 (0.06)**	**<.001**	**0.41 (0.06)**	**<.001**	**0.39 (0.06)**	**<0.001**
% of days with at least one stressor			-0.09 (0.31)	0.78	.-0.15 (0.31)	0.64	-0.25 (0.32)	0.42	-0.28 (0.31)	0.37
Age (years)			**-0.03 (0.01)**	**<.001**	**-0.03 (0.01)**	**<.001**	**-0.03 (0.01)**	**<.001**	**-0.03 (0.01)**	**<0.001**
Sex			<0.01 (0.14)	0.98	-0.02 (0.14)	0.86	-0.03 (0.14)	0.83	-0.03 (0.14)	0.81
Race			0.23 (0.31)	0.46	0.26 (0.31)	0.41	0.21 (0.31)	0.51	0.23 (0.31)	0.47
Income			**<0.01 (<0.01)**	**0.02**	**<0.01 (<0.01)**	**0.02**	<0.01 (<0.01	0.05	<0.01 (<0.01)	0.05
Physical Health and Health										

Behaviors								
BMI (kg/m^2)	0.01 (0.01)	0.45	0.01 (0.01)	0.57	<0.01 (0.01)	0.73		
Number of Chronic Health Conditions	0.02 (0.04)	0.68	0.03 (0.04)	0.52	0.02 (0.04)	0.53		
Regular exercise	-0.09 (0.17)	0.58	-0.14 (0.17)	0.43	-0.10 (0.17)	0.56		
Sleep Quality	0.15 (0.11)	0.19	0.14 (0.12)	0.24	0.12 (0.11)	0.32		
Personal Characteristics								
Neuroticism			-0.18 (0.15)	0.22	-0.16 (0.15)	0.28		
Perceived stress			**0.03 (0.01)**	**0.03**	**0.04 (0.01)**	**0.01**		
Trait Negative Affect			0.14 (0.21)	0.51	-0.94 (0.21)	0.66		
Interaction								
Negative Affect Reactivity x HF-HRV					**-1.73 (0.60)**	**0.004**		
R^2	**0.053**		**0.238**		**0.246**		**0.259**	**0.277**

Table 3. Multiple linear regression statistics for models predicting marital satisfaction

	Model 1b (Unadjusted)		Model 2b (Stressor Frequency and Demographics)		Model 3b (Physical Health and Health Behaviors)		Model 4b (Personal Characteristics)		Model 5b (Interaction)	
Parameter	*β* (*SE*)	*p*	*β* (*SE*)	*p*	*β* (*SE*)	*p*	*β* (*SE*)	*p*	*β* (*SE*)	*p*
Intercept	**8.47 (0.09)**	**<.001**	**9.06 (0.35)**	**<.001**	**9.06 (0.36)**	**<.001**	**8.97 (0.36)**	**<.001**	**9.04 (0.35)**	**<.001**
Predictor and moderator										
Negative Affect Reactivity	**- 3.09 (0.92)**	**<.001**	**-2.05 (0.80)**	**0 .01**	**-2.03 (0.81)**	**0.01**	**-2.00 (0.85)**	**0.02**	-1.22 (0.85)	0.15
HF-HRV (0.15-0.5 Hz)	**0.16 (0.08)**	**0.04**	0.14 (0.07)	0.05	0.13 (0.07)	0.06	0.13 (0.06)	0.06	**0.15 (0.07)**	**0.03**
Stressor Frequency and Demographics										
Marital Sat. (MIDUS 2)			**0.58 (0.06)**	**<.001**	**0.58 (0.06)**	**<.001**	**0.58 (0.06)**	**<.001**	**0.55 (0.06)**	**<0.001**
% of days with at least one stressor			-0.31 (0.35)	0.39	.-0.30 (0.36)	0.41	-0.19 (0.36)	0.60	-0.15 (0.35)	0.66
Age (years)			**0.02 (0.01)**	**0.02**	**0.02 (0.01)**	**0.02**	**0.03 (0.01)**	**0.01**	**0.02 (0.01)**	**0.005**
Sex			-0.28 (0.15)	0.07	-0.27 (0.16)	0.08	-0.24 (0.16)	0.13	-0.23 (0.15)	0.14
Race			-0.47 (0.35)	0.18	-0.48 (0.35)	0.18	-0.41 (0.35)	0.25	-0.45 (0.35)	0.20
Income			<0.01 (<0.01)	0.23	<0.01 (<0.01)	0.24	<0.01 (<0.01)	0.38	<0.01 (<0.01)	0.40

Physical Health and Health Behaviors								
BMI (kg/m^2)			<-0.01 (0.02)	0.90	<.01 (0.02)	0.99	<0.01 (0.01)	0.74
Number of Chronic Health Conditions			-0.01 (0.04)	0.84	-0.03 (0.04)	0.57	-0.02 (0.04)	0.57
Regular exercise			0.02 (0.20)	0.93	0.07 (0.20)	0.73	0.01 (0.19)	0.95
Sleep Quality			-0.01 (0.13)	0.96	<.01 (0.13)	0.998	0.04 (0.13)	0.77
Personal Characteristics								
Neuroticism					0.10 (0.17)	0.56	0.07 (0.16)	0.69
Perceived stress					**-0.04 (0.02)**	**0.03**	**-0.04 (0.02)**	**0.01**
Trait Negative Affect					0.39 (0.24)	0.11	0.31 (0.24)	0.19
Interaction								
Negative Affect Reactivity x HF-HRV							**2.86 (0.68)**	**<0.001**
R^2	**0.047**		**0.340**		**0.340**		**0.353**	**0.387**

Figure 1. Individual differences in stress processes **(**Williams, Smith, Gunn, & Uchino, 2011)

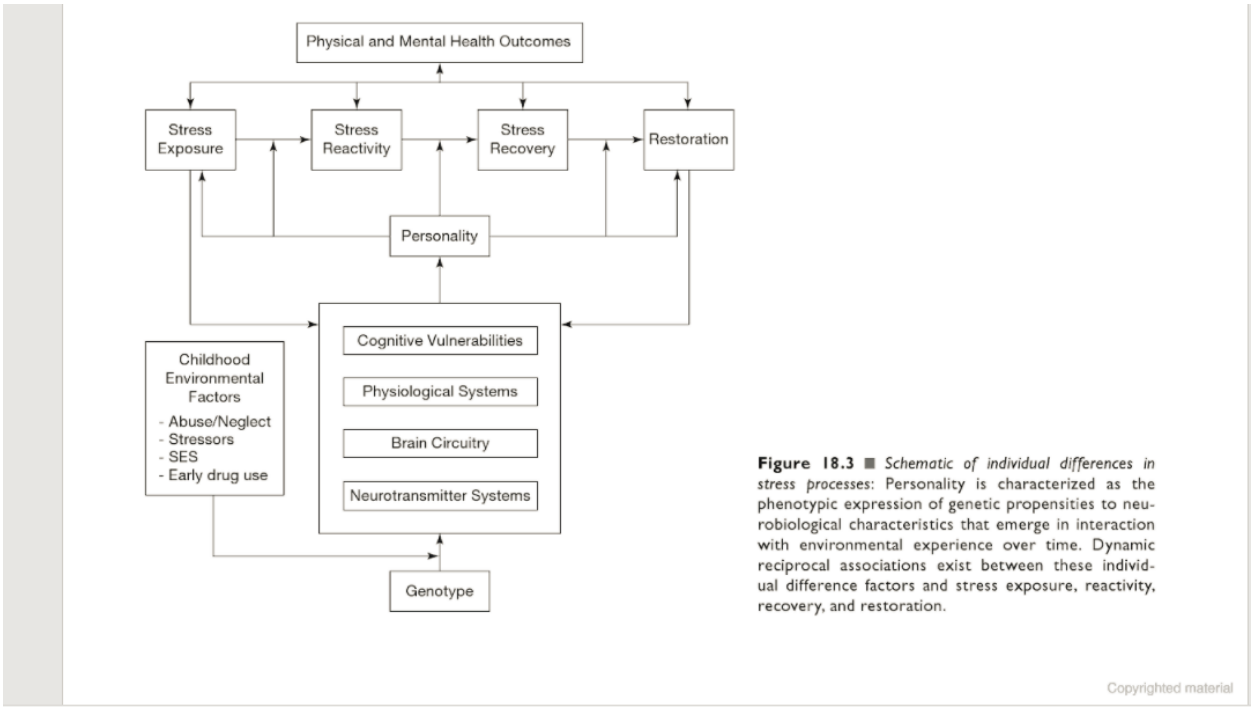

Figure 2. Strength and Strain Model of Marital Quality and Physical Health (Slatcher & Selcuk, 2017)

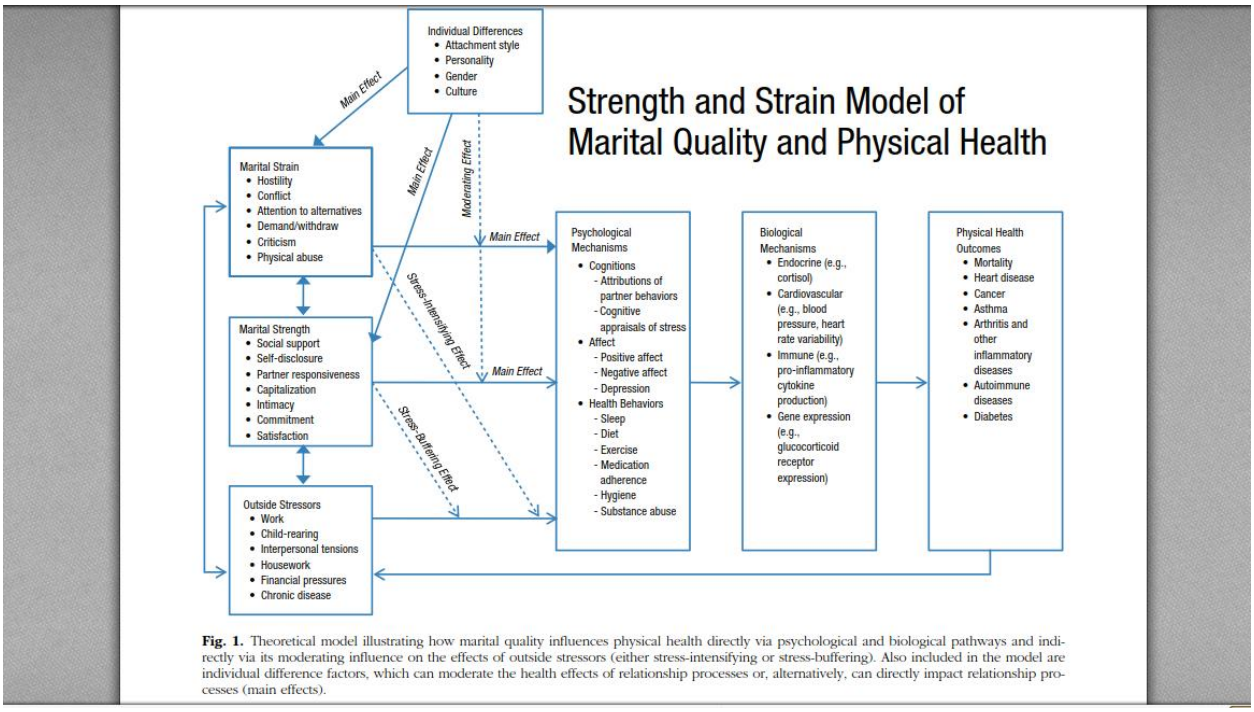

Fig. 1. Theoretical model illustrating how marital quality influences physical health directly via psychological and biological pathways and indirectly via its moderating influence on the effects of outside stressors (either stress-intensifying or stress-buffering). Also included in the model are individual difference factors, which can moderate the health effects of relationship processes or, alternatively, can directly impact relationship processes (main effects).

Figure 3. Moderation model of HRV's influence on the negative AR-marital quality link

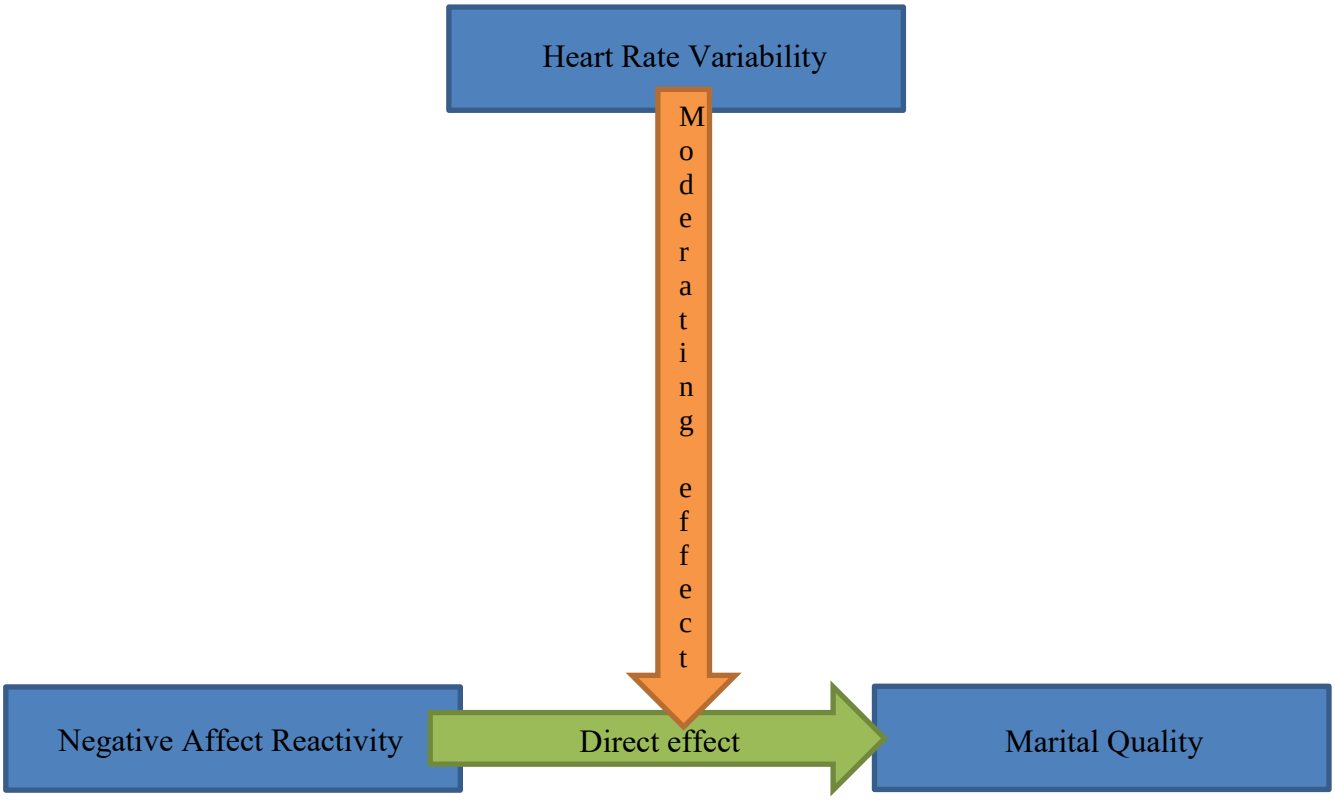

Figure 4. Simple slopes of model 5a interaction effects predicting marital risk. Confidence intervals are 95%.

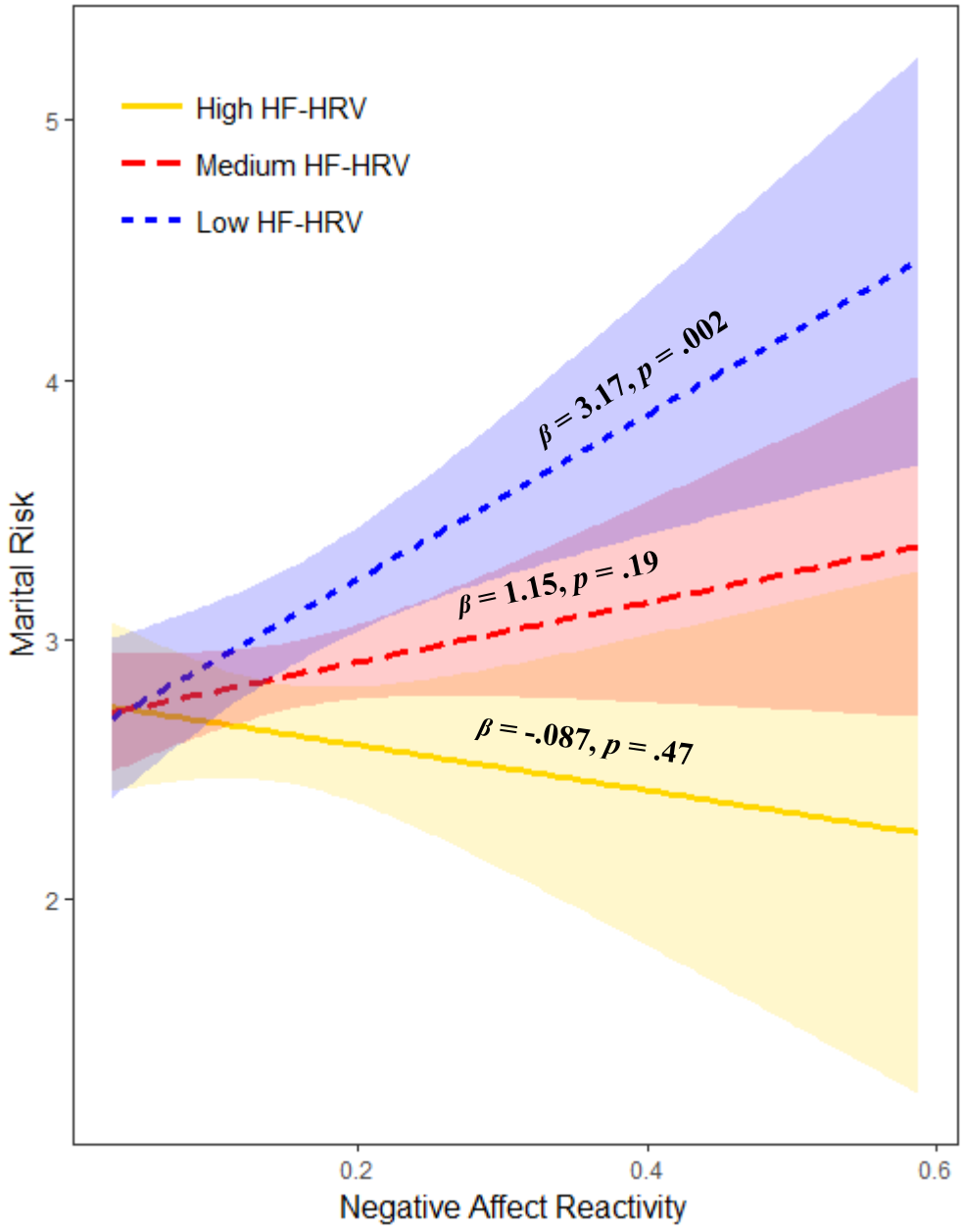

Figure 5. Simple slopes of model 5b interaction effects predicting marital satisfaction. Confidence intervals = 95%.